Distribution and Utilization of Gastropod Shells by the Hermit Crabs *Pagurus samuelis*, *Pagurus granosimanus*, and *Pagurus hirsutiusculus* at Pacific Grove, California

BY

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(6 Text figures; 1 Table)

Several species of *Pagurus* occur in the rocky intertidal zone at Pacific Grove, California. The majority of the larger hermit crabs are found in shells of *Tegula funebralis* (A. Adams, 1854), this being the only snail in the area which is both large enough and abundant enough to supply the larger pagurids with homes. It therefore appears that the *T. funebralis* population might be one of the factors limiting the hermit crab population. In inquiring into the relationship between snail and crab I tried to determine the following: (1) What species of *Pagurus* are present, how are these distributed, what factors influence this distribution? (2) What shells are used by the different species and how does this correlate with the size and distribution of the *T. funebralis* population?

The hermit crabs collected intertidally at the Hopkins Marine Station, Pacific Grove were identified using the descriptions in Schmitt (1921). The following species were found: *Pagurus samuelis* (Stimpson, 1857), *P. granosimanus* (Stimpson, 1859), and *P. hirsutiusculus* (Dana, 1857). Of the 1873 hermit crabs collected, 50% were *P. samuelis*, 40% *P. hirsutiusculus*, and only 10% were *P. granosimanus*. Samples included both young and adult specimens from each species. The young were identified by using a series of animals of graded size for each species, and noting color patterns on both antennae and body. Identifying characteristics for the younger hermit crabs are as follows: *P. samuelis* - red antennae and either white or blue bands on the walking legs; *P. granosimanus* - like adult in color; *P. hirsutiusculus* - dark olive-green antennae striped with white, ambulatory legs striped with white (never with blue), merus on both large and small cheliped very dark brown contrasting with the lighter brown of the rest of the leg. In general, both *P. samuelis* and *P. granosimanus* are relatively large, reaching an overall extended length of 6 and 7 cm, respectively, whereas *P. hirsutiusculus* is a smaller species, not frequently exceeding 4 cm in length.

To study the distribution problem, transects were taken running seaward from the shore in three different areas:

Area A. Rocky exposed coast, rich in algal growth.

Area B. Large granite outcrop with rough surf and surge, barnacles and mussels predominate.

Area C. Semi-protected rocky area, rich in algal growth. (see Wara, W., & B. Wright, 1964, for detailed descriptions and profiles of these areas.)

In each transect, samples were collected at two meter intervals, starting at the shore. The first 100 hermit crabs seen at each site were taken, or as many as could be found if 100 were not present. Collecting was not done at low tide, since at that time the hermit crabs are most difficult to find, being hidden under rocks and in crevices. The hours immediately preceding or following a low tide are better, when water covers most areas yet is shallow enough to allow collecting. Results are shown in Figures 1 and 2.

Of the three species, *Pagurus samuelis* was the only one found at the highest levels in the intertidal, while both *P. granosimanus* and *P. hirsutiusculus* occupied lower regions, areas usually covered by water. In area C, the *P. samuelis* represent the only hermit crabs found both close to shore and at the outer part of the transect because of a large rock outcropping at the outer margin.

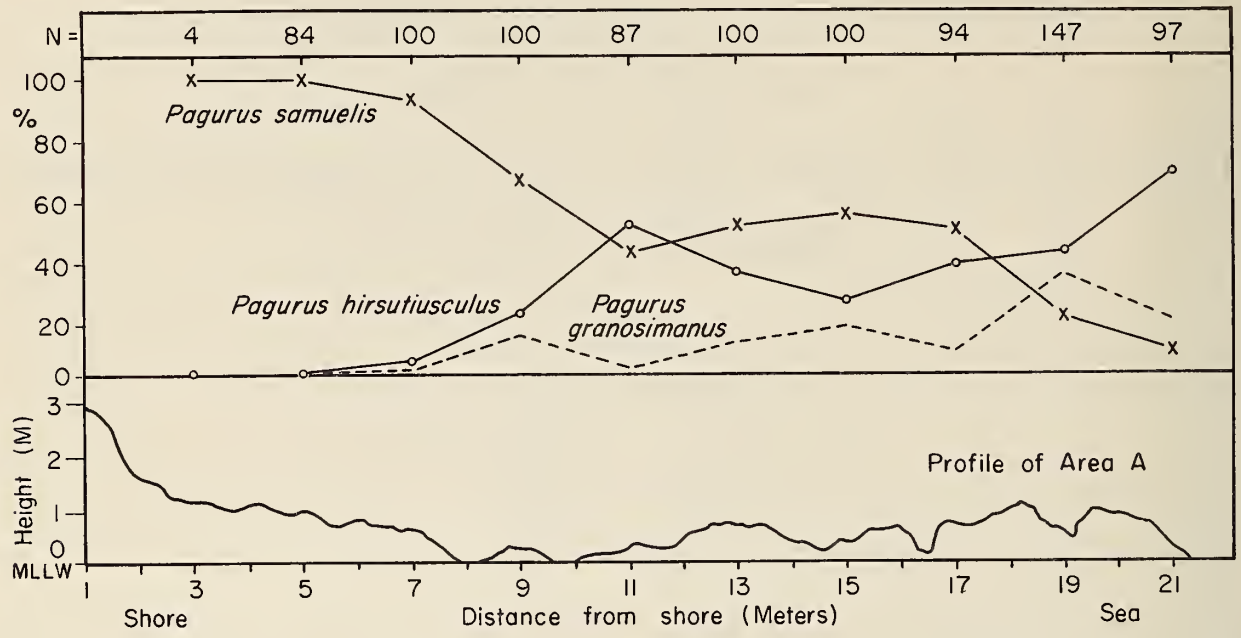

Figure 1: Relative Abundance of Three *Pagurus* Species in Area A

Collecting was done on two consecutive days, May 8 and 9, 1963, the first sunny and the second overcast, from 6:15 a. m. to 10:00 a. m. and from 7:00 a. m. to 10:30 a. m. respectively. This was from the low tide until it became too rough to collect. No sample size.

The *P. hirsutiusculus* and the *P. granosimanus* are again concentrated in the deeper lying regions, which this time are in the center of the transect. As shown by the sample size (N) there were far fewer hermit crabs at the higher sites along the transect, all that were found being taken, whereas in the lower areas there was no difficulty in finding 100 for the sample.

What can be seen intuitively in these first two graphs — that the three species are probably distributed differentially with respect to height — is clearly illustrated in Figure 3, in which the data from areas A and C are combined and species distribution is plotted against vertical position in the intertidal. Above 1.2 m only *Pagurus samuelis* is found, while this specics represents over 50% of all the hermit crabs found at 0.6 m. With increasing depth the proportion of *P. samuelis* declincs while that of both *P. granosimanus* and *P. hirsutiusculus* increases.

The data from area B (not shown) confirm these findings, but in this transect *Pagurus granosimanus* was entirely absent; however, *P. hirsutiusculus* was found at the lowest extremity of this steep transect and in approximatcly the same numbers as in the other two areas. *Pagurus samuelis* was found up to a height of about 4 feet but in far fewer numbers, sample sizes at each collecting station averaging 10.1 for this transect as a whole. Of the 97 *Pagurus* collected, only 44.3% were *P. samuelis,* 55.7% were *P. hirsutiusculus.*

Since the differences in distribution might reflect differences in ability to withstand the effects of exposure, an experiment was conducted to see if there was any difference in the survival between the three species when exposed out of water in daylight. The bottoms of three plastic dishpans were covered with dry sand. Each pan received 30 hermit crabs of one species. The *Pagurus samuelis* and *P. granosimanus* used were all large adult specimens. The *P. hirsutiusculus,* while adults, were necessarily smaller. The data are shown in Figure 4. From this test it appears that *P. hirsutiusculus* and *P. granosimanus* are less able to survive exposure than *P. samuelis;* the smaller individuals died sooner on exposure out of watcr than the larger ones. Although more experiments would be desirable, these results suggest that differences in the ability to withstand exposure help to explain the differences in distribution of the three species.

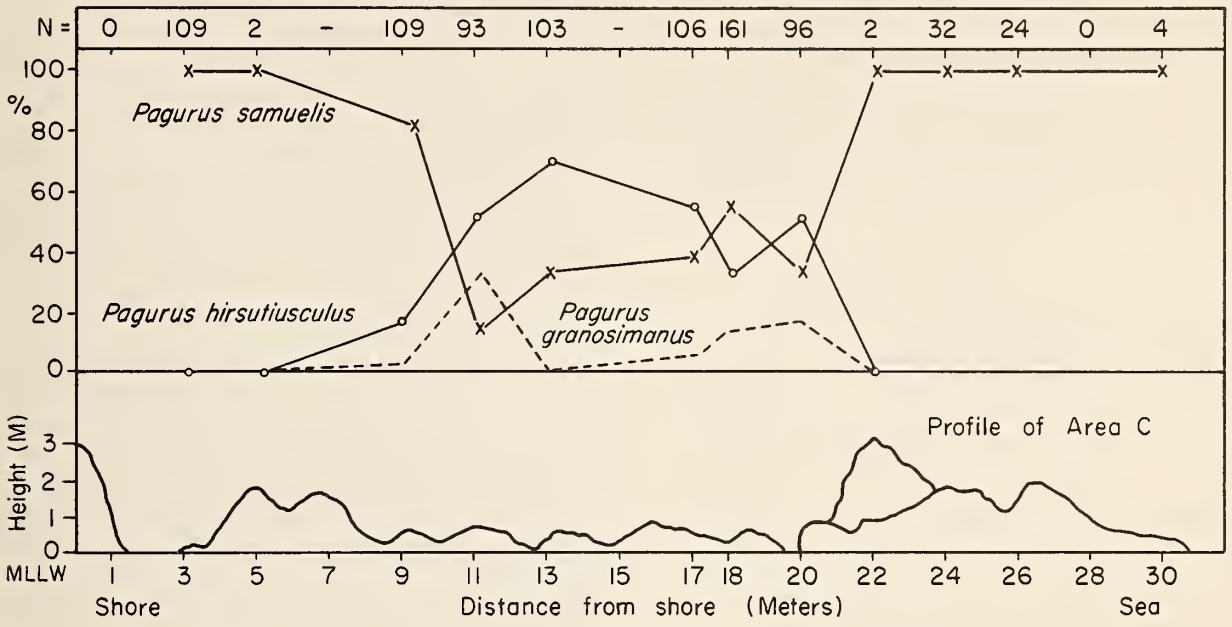

Figure 2:

Collecting was done on two consecutive days, May 16 and 17, 1963, both cloudy, from 9:00 a. m. to 12:10 p. m. and from 9:30 a. m. to 12:30 p. m., respectively. This was from a period just preceding low tide up until low tide.
N = sample size; (—) = no sample taken

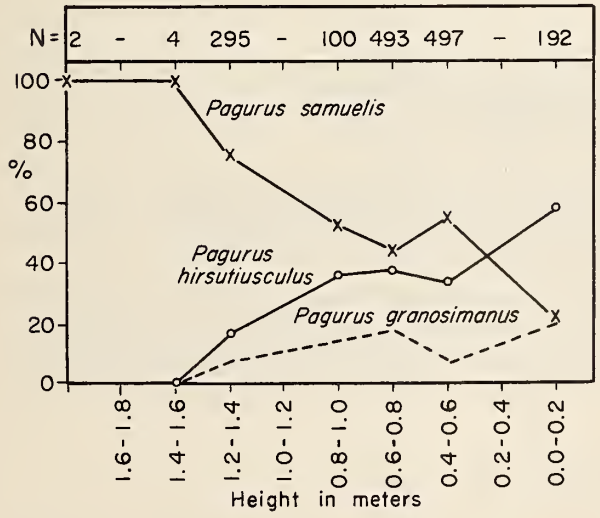

Figure 3: Relative Abundance of *Pagurus* Species at Different Elevations, Areas A and C.
N = sample size; (—) = no sample taken

Of the commonest pagurid, *Pagurus samuelis*, the smaller individuals generally live higher up in the intertidal, the largest members only deeper down. It was noted previously that the smaller *P. samuelis* seemed less able to survive exposure. That the smaller specimens seem also to live higher in the intertidal is not necessarily a contradiction because the small hermit crabs (1) are not found exposed, but rather stay under rocks, etc., and (2) are more readily able to find such protection than the larger *Pagurus* which stay in areas where they are usually submerged.

In the field it was noted that the majority of the larger hermit crabs occupied *Tegula funebralis* shells. Figure 5 compares the use made of various shells by the three species. It would appear that both *Pagurus granosimanus* and *P. samuelis* are extremely dependent on *T. funebralis* for homes, since 89% and 76%, respectively, are found in these shells. Reese (1962) reports that larger *P. granosimanus* in southern California were usually found in large *Tegula* shells, and suggests this was because, of the shells available, only those of *Tegula* were large enough to accommodate the larger crabs. Of all the *P. hirsutiusculus*, however, only 10.9% occupy *T. funebralis* shells. This latter species is much more dependent on a number of smaller snails including *Littorina spp., Calliostoma spp., Epitonium spp., Mitrella spp., Homalopoma spp.*, etc. In area B, however, the situation is interestingly different.

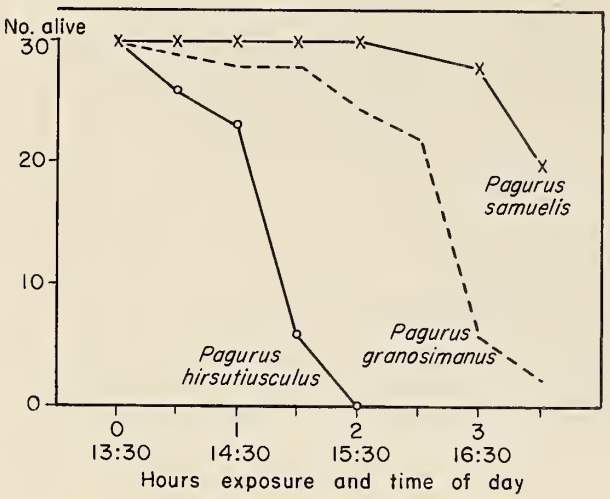

Figure 4: Survival of *Pagurus* Species on Exposure to Air and Sunlight

Of the *P. hirsutiusculus* found, none were in *T. funebralis* shells, while much greater use was made of *Littorina* and *Thais* shells than in the other two areas.

Figure 6 shows the relative utilization, by the three species of hermit crabs, of various shells which are common in the locality. For instance, of all the *Tegula funebralis* shells occupied by hermit crabs which were collected from the three transects, 73.9% were inhabited by *Pagurus samuelis*, 17.5% by *P. granosimanus*, and 8.5% by *P. hirsutiusculus*. It is quite obvious that most of the *T. funebralis* shells are used by the two larger species of hermit crabs while the smaller shells ("other") are 94.6% occupied by *P. hirsutiusculus*.

The shells utilized by different sizes of hermit crabs vary also in size. Although the hermit crabs were not measured directly, they were divided into three classes on the basis of the sizes of the shells occupied. Shell sizes in different species of snails were compared by taking the maximum basal diameter of the shells. This gives only an approximate measurement of the size of the shell and of the crabs within, because (1) any given shell can be occupied by hermit crabs of a certain range of sizes, and (2) shell sizes, as indicated by basal diameter measurements, allow only a rough size comparison when applied to shells of different species of snails. Nevertheless, the shell measurements indicate the size of the pagurid inside well enough to allow us to separate the crabs into large, medium, and small size groups. Data on species of snail shells occupied by pagurids of different size ranges are shown in Table 1. Obviously, the larger the hermit crabs grow, the more dependent they become on the *Tegula funebralis* population for homes.

This raises the interesting question: do *Pagurus granosimanus* and *P. samuelis* achieve sexual maturity before they reach a size too large to fit into any shells but those

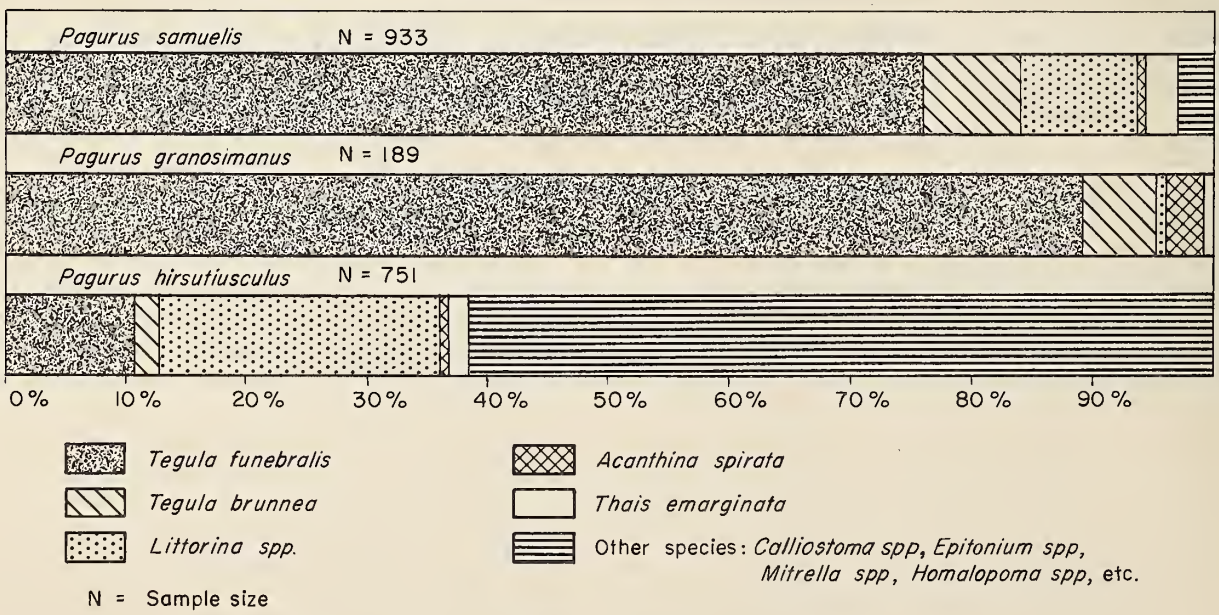

Figure 5: Comparison of Shells Occupied by Three Species of *Pagurus*

of *Tegula funebralis,* locally? Information could not be obtained on *P. granosimanus*, but for *P. samuelis* specimens as small as 1.1 cm total extended length have been collected bearing eggs. Animals this size are not heavily dependent on *T. funebralis* (see Table 1) since they can easily fit into shells less than 1.0 cm in greatest basal diameter. Since sexual maturity is, in *P. samuelis,* attained relatively early, this species (like *P. hirsutiusculus*) is probably able to survive and reproduce in areas where shells suitable to house larger individuals are not available. However, the number of eggs borne by the smaller sizes of *P. samuelis* is very much less than the number produced by a fully grown specimen. Therefore, reproductive potential in the absence of large (e. g. *T. funebralis*) shells would be lower.

Area B, as cited already, differed from the other two transects. Insufficient food could explain its small population. Another possible factor, however, might be the lack of available shells for use as homes. The *Tegula funebralis* population in this area is relatively small (see WARA, W., & B. WRIGHT, 1964). The number of *Pagurus hirsutiusculus* is not noticeably less — and this is the one species of the three that does not rely heavily on *T. funebralis* shells for homes. On the other hand, there are relatively few *P. samuelis* and no *P. granosimanus* in this area. The *P. samuelis* here make much greater use of *Thais* and *Littorina* shells — these snails being found in much greater abundance here than in the other areas. Perhaps, then, the two larger species of *Pagurus* are limited by the lack of suitable shells even though a few *P. samuelis* were found here. It is possible that the reason no *P. granosimanus* were found in this area was that they do not reach sexual maturity until they have attained a much larger size; however, this was not determined.

Table 1

	Greatest Basal Shell Diameter		
	< 1.0 cm	1.0 to 2.0 cm	2.0 to 3.0 cm
Tegula	N = 107	N = 488	N = 289
funebralis	% = 15.6	% = 83.7	% = 94.4
Tegula	N = 44	N = 18	N = 16
brunnea	% = 7.5	% = 3.1	% = 5.3
Thais spp.	N = 10	N = 34	N = 1
	% = 1.7	% = 5.3	% = 0.3
Acanthina spp.	N = 4	N = 12	N = 0
	% = 0.7	% = 2.1	% = 0
Littorina spp.	N = 202	N = 19	N = 0
	% = 29	% = 2.6	% = 0
Other species	N = 330	N = 15	N = 0
	% = 47.4	% = 2.5	% = 0

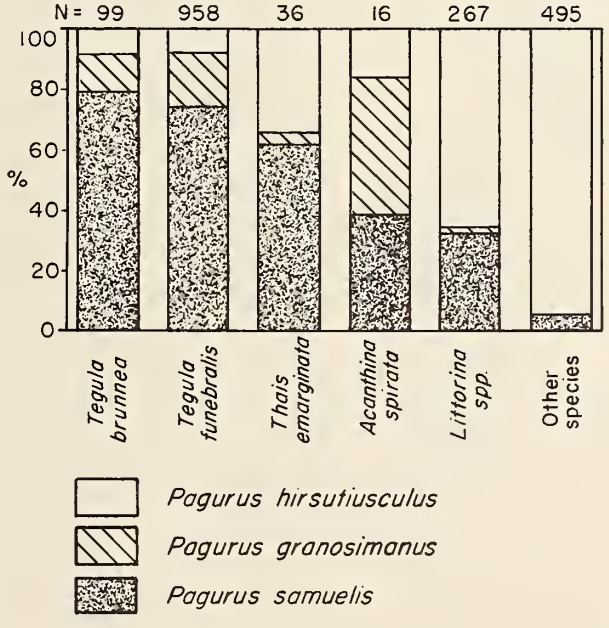

Figure 6: Utilization of Shells by *Pagurus* in Areas A, B, and C.

SUMMARY

1. Of the three species of hermit crabs found in the intertidal zone at Hopkins Marine Station, Pacific Grove, *Pagurus samuelis* is the only one encountered at positions higher than about 1.2 m, *P. hirsutiusculus* and *P. granosimanus* being found lower.
2. Of the three species, *Pagurus samuelis* appears to be able to survive exposure out of water better than the other two. Adults of *P. hirsutiusculus* are least able to withstand exposure to air in sunlight.
3. The three species make use of various shells to different degrees. Eighty-nine % of the *Pagurus granosimanus* and 75.9% of the *P. samuelis* collected occupied *Tegula funebralis* shells, whereas, the smaller *P. hirsutiusculus* tended to occupy shells of smaller snails such as *Epitonium, Mitrella, Homalopoma,* etc., to a greater degree.
4. The bigger pagurid individuals are largely dependent on *Tegula funebralis* for homes whereas the smaller sized hermit crabs are not, and occupy a variety of small shells.
5. Both *Pagurus samuelis* and *P. hirsutiusculus* attain sexual maturity at a relatively small size and thus are not completely dependent on *Tegula funebralis* for the survival and reproduction of the species. However, when larger shells are not available the reproduction potential in *P. samuelis* may be greatly reduced since the smaller individuals produce far fewer eggs than the larger ones.

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